T-45A HIGH ANGLE OF ATTACK TESTING

U.S. Naval Test Pilot School
Forty-Sixth Annual
Reunion and Symposium

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Narrative

- VIDEO - Inverted spin with anti-spin chute deployment
- Welcome symposium attendees.
- Introduce presenters.

TO WHOM IT MAY CONCERN:

Here is a copy of Professional Papers written by various people here at the Naval Air Warfare Center Aircraft Division. It was requested that a copy of each of the professional papers be sent to DTIC for retention.

If you have any questions, please contact Dorothy Reppel, 326-1709 or (301) 826-1709.

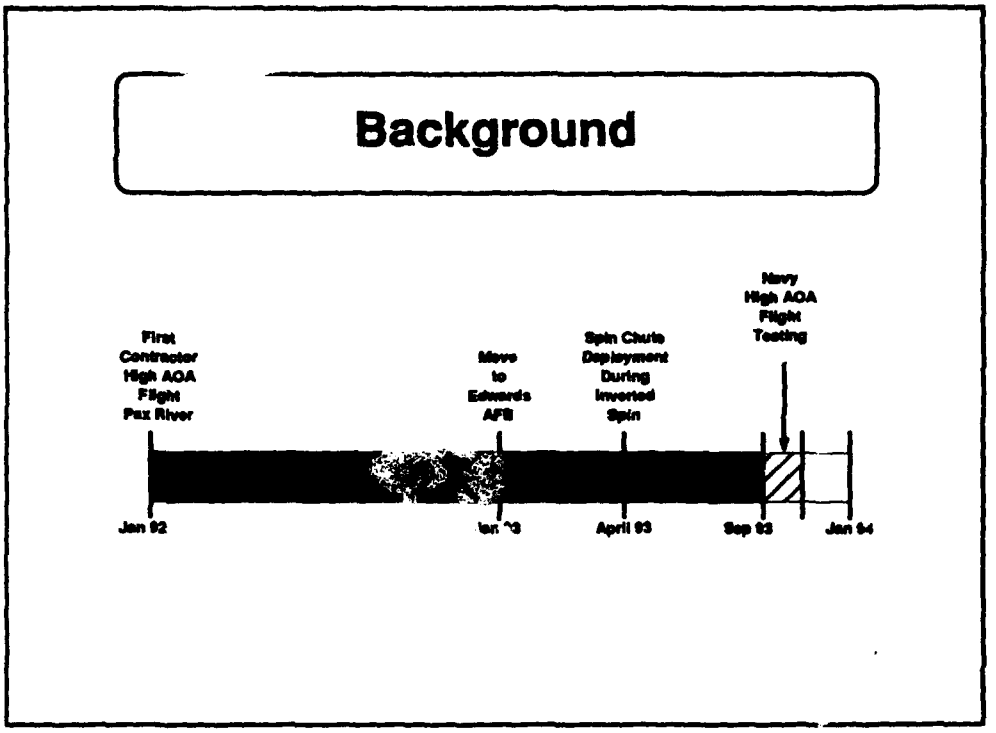
P.S. All the enclosed papers have been cleared for public release.

Overview

- **Background**
- **Purpose**
- **Scope/Method**
- **Results**
- **Follow-On Testing**
- **Questions**

Narrative

- HAOA testing background to include contractor and Navy
- Purpose of Navy testing which included ACM, OCF, Zero A/S, Departure Resistance, Spins, and engine operability
- Scope and Method of Navy testing
- Results - Discussion of the results as they relate to all aspects of the T-45 mission
- Required follow-on testing as seen by the test team
- Questions



Narrative

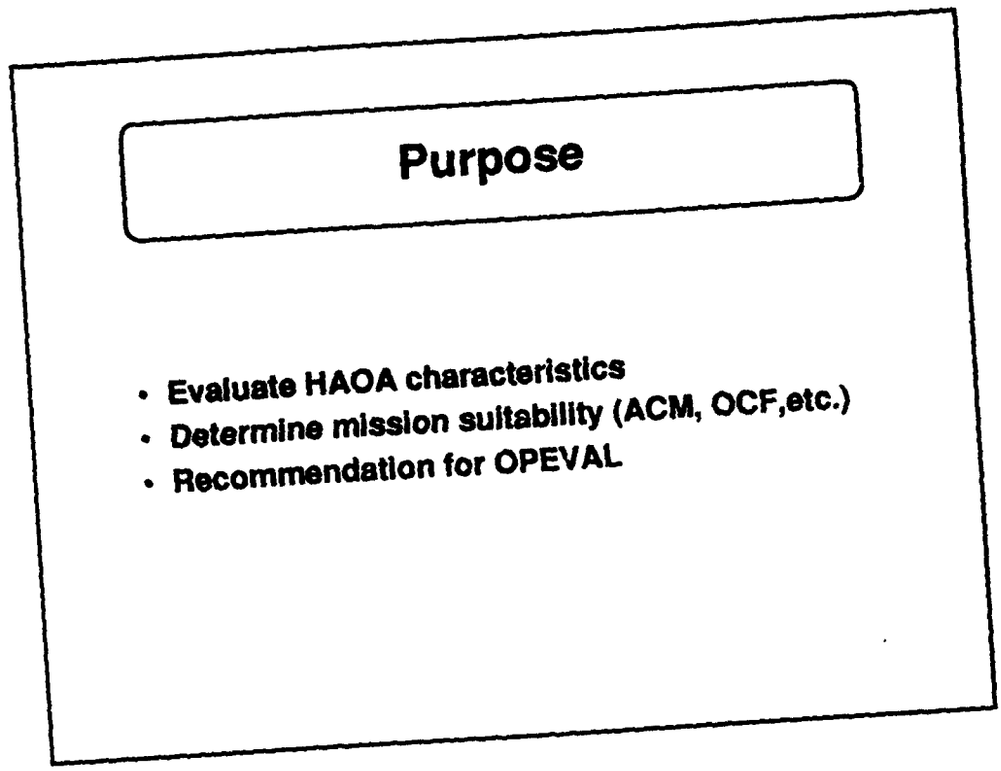
- Contractor High Angle of Attack (HAOA) testing commenced on 18 Jan 92
- Testing moved to EAFB due to:
  - Likeliness of the engine to surge during intentional departures/spins and concerns for engine relight capability
  - T-45 is a single engine airplane
- Contractor test pilot encountered an inverted spin mode which did not respond to recovery controls and required deployment of spin chute (video shown at beginning of brief)
- Spin chute failed structurally and did not effect spin recovery
- Recovered when controls neutralized
- Using six degree of freedom simulation, the contractor has predicted that the inverted spin mode is potentially unrecoverable
- Navy testing began September 1993

Contractor Testing

- **Airplane Modifications**
- **Approximately 130 flights**
- **Very departure resistant**
- **Upright and inverted spin modes**
- **Engine health issues**

Narrative

- Airplane modifications specific to spin tests
  - Irreversible hydraulically powered ailerons and all moveable stabilator
  - Reversible rudder with no-float mechanism-no mods
  - Hydro-mechanical engine fuel control-no mods
  - Typical HAOA emergency systems (spin chute, negative g restraint, cockpit indicators, extra hydraulic accumulators, split electrical buss, emergency oxygen system, etc.)
- Approximately 130 flights
- Very departure resistant except during negative AOA rolls, rolling cross controls, and vertical maneuvers/tailslides
- Two oscillatory upright spin modes identified
  - Oscillatory 25 deg AOA mode
  - Oscillatory/divergent 60 deg AOA mode
  - VIDEO - Upright spin with transition to inverted spin
- Two inverted spin modes identified
  - Steady -60 deg AOA mode
  - Steady -30 deg AOA mode (potentially unrecoverable)
- Engine Characteristics
  - Testing proved that engine surges were likely during dynamic motions (i.e. departures and spins)
  - Idle power greatly reduced occurrence rate of engine surges



Narrative

- Evaluate T-45A high AOA flying qualities and propulsion system characteristics
- Determine suitability of T-45A to perform Air Combat Maneuvering and Out-of-Control Flight Training missions

Scope

- **Edwards AFB**
- **47 solo flights**
- **Multiple loadings / full C.G. range**
- **Prohibited maneuvers**

Narrative

- Evaluation conducted at EAFB / Dry Lake Beds
- 47 solo flights for 52 flight-hours
- Clean,symmetric,and asymmetric stores
- Two pilots
- Restrictions to Navy testing based on contractor testing, NAVAIR concurrence and FTEG/SATD discussions
- Unlimited maneuvering, except:
    - No intentional departures which would couple down to negative AOA's
    - No cross control inputs in excess of 90 deg bank angle change
    - No upright spin attempts using lateral stick inputs
    - No intentional inverted spins
    - No rolls at less than -1.0 g

Method

- **Departure Resistance**
- **Out-of-Control Flight (OCF) Training Maneuvers**
- **Upright Spins**
- **Vertical maneuvering**
- **Operational maneuvers**
- **ACM**

Narrative

- Following maneuvers performed during HAOA testing:
- Departure Resistance maneuvers:
  - Wide range of entry AOA's - Full Forward (FFS) to Full Back Stick(FBS)
  - Wind Up Turns to FBS from 0.4-0.9 TMN
  - 180 and 360 deg Bank-to-Bank Rolls using a combination of lateral stick only, rudder only, and lateral stick and rudder only
  - Cross Control inputs through 90° bank angle change
  - Buildup for operational maneuvering and ACM testing
  - Clean up of contractor demonstration testing (Clean, asymmetric stores(2500 ft-lb)and symmetric stores
- OCF Training Maneuvers consisted of 180° bank-to-bank lateral stick only and rudder only rolls at FBS from 0.4 to 0.6 TMN in order to satisfy OCF training
- Upright Spins or Hawk Mode Spins consisted of rudder and longitudinal stick input
- Vertical maneuvers (defined as pitch attitude of 70 to 110° and airspeed less than 100 kts) were evaluated to determine NATOPS vertical recovery procedures, vertical maneuvering characteristics, and spin susceptibility
- Knock-it-off criteria
- Operational maneuvering and individual canned basic fighter maneuvers with student representative maneuvering
- 1 v 1 ACM engagement s with another T-45 as threat aircraft

Departure Resistance

- **Full back to full forward stick evaluation**
- **Departure resistant**
- **Exceptions:**
  - **Full forward stick rolls**
  - **Sustained cross controls**
  - **Sustained coordinated maneuvers at negative AOA's**

Narrative

- Departure resistance maneuvers flown from full back and full forward stick.
- Maneuvers flown from 0.4 to 0.9 TMN
- VIDEO - 0.9 TMN lateral stick roll
- Maneuvers flown included full pedal rolls (250 lb), full lateral stick rolls, full coordinated rolls, full cross controls
- Very departure resistant to most mission relatable inputs
- The airplane is susceptible to departure during the following not so mission relatable control inputs:
  - Sustained full forward stick rolls
  - Sustained rolling cross controls
  - Sustained coordinated maneuvers at negative AOA's

Vertical Maneuvers

- **44 vertical maneuvers**
- **75° θ or less, satisfactory and surge-free**
- **±10° from vertical, susceptible to inadvertent inverted spin and engine anomaly**

Narrative

- 44 vertical maneuvers including true tailslides
- Various control inputs(FFS,FBS, neutral controls), pitch attitudes (70,80,90,100,etc.) and airspeeds (100,50,0), max altitude was approximately 34,000 ft.
- All recoveries included forcible centering pedals
- All vertical maneuvers at 75 deg pitch attitude or less were satisfactory and surge-free
- VIDEOS - Typical vertical maneuver/Incipient inverted spin from tailslides
- Vertical maneuvers within 10 deg of vertical and less than 100 knots were not considered satisfactory
    - 1 out of 10 resulted in negative AOA departure or incipient inverted spin
    - 5 out of 10 resulted in engine anomaly (including locked surges and flameouts)
- Susceptible to inadvertent inverted spin entry from vertical maneuvers within 10 deg of vertical

OCF Training

- **TEMP requirements**
- **Contractor recommended departures for OCF training:**
  - **Lateral stick rolling departure**
  - **Rudder induced departure**
- **Capable of performing designated maneuvers**
- **All departures extremely benign**
- **Upright Spins**

Narrative

- The T-45A is not required to be an out-of-control flight/spin trainer.
- T-45A required to perform contractor recommended departures for Student Naval Aviators(SNA) :
  - Lateral stick rolling departure
  - VIDEO- Lateral stick rolling departure
  - Rudder induced departure
- Although the T-45 is capable of performing all departures, the lateral stick rolling departure and the rudder induced departure are extremely benign and of little training value
- Not a good visual description of a departure for SNA's
- Upright spins also evaluated as potential OCF maneuver
  - Entry conditions included airspeed, angle of bank, and AOA
  - Terminated criteria included airspeed, sideslip or roll rate oscillations became large, altitude, departure, or engine surge
- Upright spins unacceptable because of oscillatory nature and potential to transition to inverted spin

ACM

- **Buildup**
- **1 v 1**
- **Operational Maneuvers/ACM well inside the region where the T-45 is departure resistant**
- **Problem areas:**
  - **Energy fight to position fight transition**
  - **Insufficient rudder control power**

Narrative

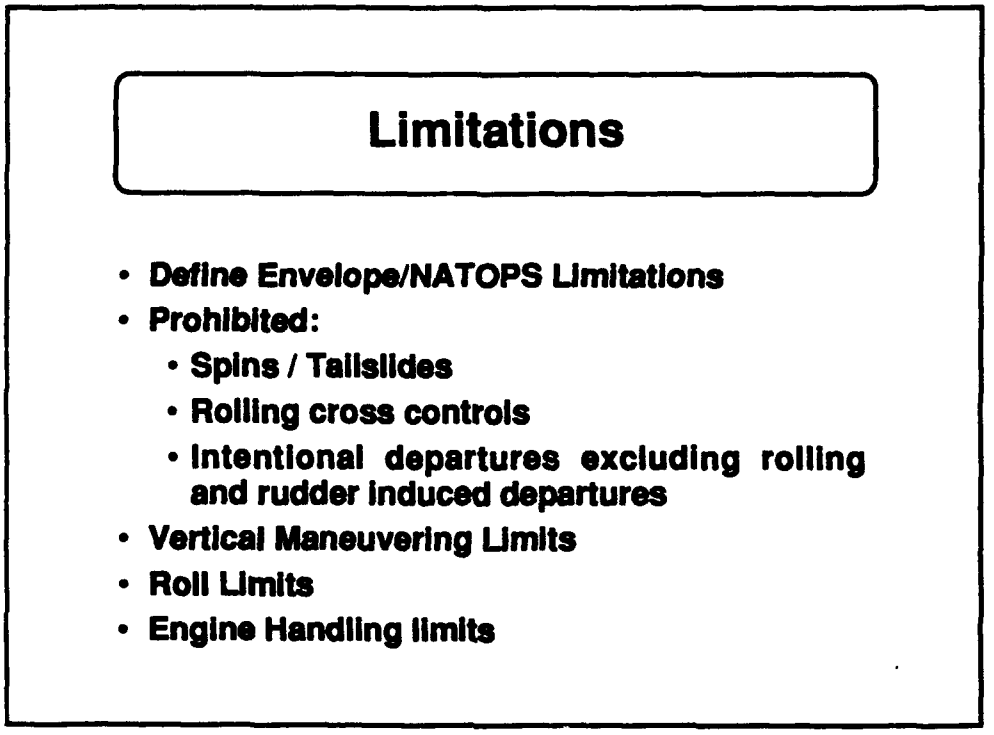
- All ACM maneuvers initially evaluated single-ship as individual, canned maneuvers
- Buildup in pilot inputs from nominal to aggressive control inputs and throttle manipulations throughout the maneuvers
- Conducted 1 v 1 ACM engagements against another T-45
- T-45 very departure resistant during ACM training maneuvers
- Control inputs and resulting airplane dynamics (peak AOA, peak sideslip, peak roll rates, and peak yaw rates) much less than those experienced during the departure resistance maneuvers
- Maximum performance obtained when maneuvering at buffet onset
- Buffet onset occurs at fairly low g: 200 kts ≈ 2.1g, 300 kts ≈ 3.5g
- Fine line between onset, limit, and tracking buffet
- Attempting to maneuver past buffet onset results in pitch bucking motion which precludes fine tracking and reduces turn rate
- Difficult to teach transition from energy fight to position fight due to low g available (Part II)
- Roll rate using rudder(pedal forces of up to 250 lb) as low as 40 °/sec
- Could not perform displacement rolls or high-g over the top
- Difficult to teach all axis control during ACM due to insufficient rudder control power (Part II)

Engine Operability

- **Better than expected**
- **Engine will surge**
- **Low/high power setting surges**
- **Limitations**
- **Satisfactory for mission**

Narrative

- Engine performed better than expected during operationally representative maneuvering
- Engine will surge (inverted spins, departures, tailslides, non-mission relatable inputs i.e. abrupt pull to FBS)
- 66 engine surges during HAOA testing)
- Low power setting surge - time to react / marginal cues
- High power setting surge - rapid temperature rise / marginal cues
- Surge can be cleared with a chop to IDLE
- If chop to idle does not clear the surge, an engine shutdown with immediate relight will usually clear the surge
- Throttle shall be at idle for:
    - Abrupt pulls to full back stick
    - Abrupt inputs at full back stick
    - Airspeeds less than 85 KCAS at altitude above 15,000 ft MSL
    - Departure or Spin
- Engine characteristics are satisfactory for the mission



Narrative

- As a result of HAOA testing, the following maneuvers are prohibited in the T-45A airplane:
  - Intentional spins or tailslides
  - Rolling cross control maneuvers of more than 60 deg bank angle change
  - Intentional departures except for Rolling Departure and Rudder-Induced departure
  - *Rolls at less than:*

    Negative 1.0 g at less than 260 KCAS

    Negative 0.2 g at or greater than 260 KCAS, but less than 0.80 Mach

    Positive 1.0 g at or greater than 0.80 Mach

    Lateral/directional inputs below 3 units AOA
- Vertical Maneuvering Limits:
  - For pitch attitudes of less than 70 deg and airspeed less than 100 KCAS: Throttle as desired, Push to 5 to 10 units, or pull to 17 units to nearest horizon
  - For pitch attitudes of greater than 70 deg and airspeed less than 100 KCAS: Throttle to IDLE, Neutralize controls; forcefully center rudder pedals
- Throttle shall be at idle for:
  - Abrupt pulls to full back stick
  - Abrupt inputs at full back stick
  - Airspeeds less than 85 KCAS at altitude above 15,000 ft MSL
  - Departure or Spin

Summary

- **Very departure resistant**
- **Fleet envelope**
- **ACM / OCF mission suitable**
- **Problem areas**
- **Ready for OPEVAL**

Narrative

- The airplane was found to be very departure resistant during the *vast majority of mission relatable operational maneuvers*
- Defined a usable envelope and provided prohibited maneuver and control/ engine limitations to limit the likeliness of encountering adverse flying qualities
- ACM and OCF training is satisfactory for trainer mission
- Problem areas:
    - Prone to dynamic departures and possible entry in unrecoverable inverted spin during:
        - Slow speed (less than 100 KCAS) at extreme nose high attitudes (within 10 deg of the vertical)
        - Coordinated inputs at negative AOA's through greater than 180 deg bank angle change
        - Cross control inputs through greater than 90 deg bank angle change
    - HAOA flying qualities are not satisfactory
    - HAOA flying qualities will be considered satisfactory upon correction of susceptibility to inadvertent entry into potentially unrecoverable inverted spin
- Recommended that the T-45A proceed to Phase II OPEVAL

Still To Come

- **Demonstrate Inverted spin recovery controls**
- **Powered Rudder**

Narrative

- The purpose of upcoming flight testing is to determine and demonstrate inverted spin recovery controls (May-June 94)
- Follow-On HAOA testing will likely be done at Pax since engine relight capability has been shown to be excellent (66 surges with no failed relights during HAOA testing at Pax and EAFB)
- Powered rudder may be incorporated into the T-45 to improve OCF Training capability and to aid in spin recovery

Questions